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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)		10681-006 **10/018324**

INTERNATIONAL APPLICATION NO. PCT/GB00/02274	INTERNATIONAL FILING DATE 12 June 2000	PRIORITY DATE CLAIMED 10 June 1999

TITLE OF INVENTION
MULTIBAND ANTENNA

APPLICANT(S) FOR DO/EO/US
Langley, Richard Jonathan

Applicant herewith submits to the United States Designated/ Elected Office (DO/EO/US) the following items under 35 U.S.C. 371:

1.　☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.

2.　☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3.　☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).

4.　☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5.　☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
　　　　a. ☐ is transmitted herewith (required only if not transmitted by the international Bureau).
　　　　b. ☒ has been transmitted by the International Bureau.
　　　　c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)

6.　☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7.　☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
　　　　a. ☒ are transmitted herewith (required only if not transmitted by the International Bureau).
　　　　b. ☐ have been transmitted by the International Bureaus.
　　　　c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
　　　　d. ☐ have not been made and will not be made.

8.　☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 37(c)(3)).

9.　☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10.　☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11.　☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12.　☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13.　☒ A FIRST preliminary amendment.
　　　☐ A SECOND or SUBSEQUENT preliminary amendment.

14.　☐ A substitute specification.

15.　☐ A change of power of attorney and/or address letter.

16.　☒ Other items or information: copy of Form PCT/RO/101; copy of International Application as published; copy of International Search Report; copy of Notification of Transmittal of IPER; copy of IPER, including amended page 4 of specification and amended claims 23-28; copy of Notification Concerning Submission or Transmittal of Priority Document; and copy of Notice Informing the Applicant of the Communication of the International Application to the Designated Offices.

NAL APPLICATION NO.
0/02274

INTERNATIONAL FILING DATE
12 June 2000

1U/U18324

JC13 Rec'd PCT/PTO 10 DEC 2001

☒ The U.S. National Fee (35 U.S.C. 371(c)(1)) and other fees as follows:

CLAIMS				
(1)FOR	(2)NUMBER FILED	(3)NUMBER EXTRA	(4)RATE	(5)CALCULATIONS
TOTAL CLAIMS	28 -20	8	X $18.00	$ 144.00
INDEPENDENT CLAIMS	4 -3	1	X $84.00	84.00
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $280.00	☐

BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5)):
CHECK ONE BOX ONLY

☐ International preliminary examination fee paid to USPTO (37 CFR 1.482)
. . . . $710.00 $ 890.00

☐ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))
. . . . $740.00

☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO $1,040.00

☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2) to (4) $100.00

☒ Filing with EPO or JPO search report $890.00

Surcharge of $130.00 for furnishing the National fee or oath or declaration later than 20 30 mos. from the earliest claimed priority date (37 CFR 1.492(e)).

	TOTAL OF ABOVE CALCULATIONS	=	1,118.00

Reduction by 1/2 for filing by small entity, if applicable. Affidavit must be filed also. (Note 37 CFR 1.9, 1.27, 1.28).   − $ 0.00

	SUBTOTAL	=	1,118.00

Processing fee of $130.00 for furnishing the English Translation later than 20 30 mos. from the earliest claimed priority date (37 CFR 1.492(f)).   +

	TOTAL FEES ENCLOSED	$	1,118.00

a. ☐ A check in the amount of $ 710 to cover the above fees is enclosed.

b. ☒ Please charge Deposit Account No. 16-1150 in the amount of $ 1,118.00 to cover the above fees. A copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 16-1150. A copy of this sheet is enclosed.

18. ☐ Other instructions
       n/a

19. ☒ All correspondence for this application should be mailed to
       PENNIE & EDMONDS LLP
       1155 Avenue of Americas
       New York, N.Y. 10036-2711

20. ☒ All telephone inquiries should be made to

Steven P. Underwood (Reg. No. 47,205)

Charles E. Miller	For _Charles E. Miller_	24,576	December 10, 2001
NAME	SIGNATURE	REGISTRATION NUMBER	DATE

NY2 - 1265020.1

Express Mail No.: <u>EL 477 032 875 US</u>

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application of: Langley, Richard Jonathan

Application No.: Not yet assigned - National stage of PCT/GB00/02274	Group Art Unit:
Filed: Herewith	Examiner: Not yet assigned
For: MULTIBAND ANTENNA	Attorney Docket No.: 10681-006

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Please cancel claims 1-28, and add claims 29-56:

29.   A RF antenna comprising a single conductor arranged in polygonal spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, the polygonal spiral form comprising successive linear sections, each forming an angle with a succeeding or preceding one, the total length of the conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

30.   An antenna as in claim 29, wherein the lengths of the sections and the angles between them are such that the antenna is linearly polarized.

31.   An antenna as in claim 29, wherein opposite sides of the generally spiral form comprise at least three major sides that are markedly non-parallel with each other.

32.   A RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, wherein an envelope of the generally spiral form comprises three, four, or five major sides that are markedly non-parallel with each other, the total length of the conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

33.   A RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, an envelope of the generally spiral form comprising three major sides disposed so as to lie in a triangular relationship, the total length of the conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

34.   An antenna as in claim 31, wherein an end of each major side merges with an end of an adjoining major side.

35.   An antenna as in claim 31, wherein the lengths of and angles between the major sides are such that the antenna is linearly polarized.

36.   An antenna as in claim 35, wherein the aspect ratio of an overall envelope of the generally spiral form is chosen such that the antenna has a required ratio of horizontal and vertical polarization.

37.   An antenna as in claim 32, wherein an overall envelope of the generally spiral form is substantially in the shape of an equiangular triangle.

38.   An antenna as in claim 32, wherein an overall envelope of the generally spiral form is substantially in the shape of an isosceles triangle.

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39.   An antenna as in claim 38, wherein, when the antenna is disposed generally upright, a top side of the overall envelope of the spiral form is shorter that the other two sides of the overall envelope.

40.   An antenna as in claim 29, wherein co-extensive parts of the spiral form extend generally parallel to each other.

41.   An antenna as in claim 37, wherein, when the antenna is disposed generally upright, from its one end the conductor is adapted to extend upwardly at an angle, then generally horizontally, then generally downwardly at an angle to a point adjacent its one end, thereby forming a first outer side, a top outer side, and a second outer side, respectively, and then to extend upwardly, horizontally, and downwardly within the outer sides to form a first inner side, a top inner side, and a second inner side, respectively.

42.   An antenna as in claim 41, wherein the first and top inner sides are each approximately 80% as long as the respective first and top outer sides, and wherein the spacing between the first outer side and first inner side and between the top outer side and the top inner side are each approximately 10% of the length of the first outer side.

43.   An antenna as in claim 42, wherein the second inner side is approximately one-third the length of the second outer side.

44.   An antenna as in claim 29, wherein one end of the conductor is an outer end of the spiral form.

45.   An antenna as in claim 29, and also comprising a stub antenna extending from the one end of the conductor so as to be alongside an outermost portion of the spiral form, the stub antenna providing a required additional frequency.

46.   An antenna as in claim 41, and also comprising a stub antenna extending from the one end of the conductor so as to be alongside the first outer side.

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47.   An antenna as in claim 46, wherein the stub antenna is approximately 40% the length of the first outer side.

48.   An antenna as in claim 47, wherein spacing of the stub antenna from the first outer side is approximately 10% the length of the stub antenna.

49.   An antenna as in claim 48, wherein the antenna has resonant frequencies at approximately 100 MHz and 220 MHz.

50.   An antenna as in claim 29, further comprising a ground plane functionally adjacent the conductor.

51.   An antenna as in claim 29, in combination with a further antenna, the two antennas being arranged as a dipole.

52.   An antenna as in claim 29, mounted on a substrate for attachment to a window or other surface.

53.   A window or vehicle body panel or other vehicle fitment comprising an antenna as in claim 1.

54.   A window or vehicle body panel or other vehicle fitment as in claim 53, wherein the window or body panel or other vehicle fitment forms a dielectric between the antenna and the ground plane.

55.   A method of manufacturing an antenna, comprising disposing or defining a single conductor in a polygonal spiral form with a feed connection at or adjacent one end thereof, and selecting the spacing between adjacent co-extensive sections of the polygonal spiral form or an overall length of the conductor such that the antenna has a plurality of required resonance frequencies.

56.   A method as in claim 55, comprising selecting the length of and angles between successive sections of the polygonal spiral form such that the antenna has a required ratio of horizontal and vertical polarization.

Remarks

Claims 1-28 of the International Application submitted herewith have been canceled and replaced with claims 29-56, which are revisions of claims 1-28 designed to better comply with United States Patent and Trademark Office claiming standards.

In view of the above Amendment, Applicants believe the subject application has been placed in condition for allowance, and such action is respectfully requested. Please charge appropriate fees, if any, to Deposit Account 16-1150.

Respectfully submitted,

Date December 10, 2001

Steven P. Underwood (Reg.No. 47,205)

24,576

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NY2 - 1266144.1

MULTIBAND ANTENNA

This invention relates to antennas, particularly but not exclusively for installation in cars or other vehicles.

With the increasing amount of media broadcasting including the new digital audio broadcasting (DAB) there is an increased need for a single antenna system to cover all bands.

5   Ideally a system for an on car antenna should be small, low cost and unobtrusive. For most automobile communication systems a standard wire mast antenna or whip antenna is used but this is obtrusive on a car and susceptible to damage. Additional band requirements could lead to additional obtrusive antennas.

A printed or wire antenna being low profile is a good alternative and can be mounted

10   conformally. One such form of antenna is disclosed in Helical and Spiral Antennas by Hisamatsu Nakano (Research Studies Press Ltd. 1987). Chapter II describes a two-wire square spiral antenna in which two arms of the spiral extend outwards from a feed at the centre of the spiral. This antenna radiates when the circumference of the spiral is about two wavelengths, the resultant radiation usually being circularly polarised.

15   The present invention adopts a completely different approach, namely a single-wire polygonal spiral whose radiating frequency bands are related to the overall length of the wire and the proximity of the successive turns of the spiral to each other. Although discussed for convenience in the context of a transmitting antenna, the invention of course applies equally to an antenna used in a receiving mode.

20   According to the invention there is provided a RF antenna comprising a single conductor arranged in polygonal spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, the polygonal spiral form comprising successive linear sections each forming an angle with a succeeding or preceding one, the total length of the conductor and the spacing of adjacent

25   co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

Preferably, the length of the sections and the angles between them are such that the antenna is linearly polarised.

Preferably, opposite sides of the generally spiral form comprises at least three major sides which are markedly non-parallel with each other.

5   The invention may further be described as a RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, wherein the envelope of the generally spiral form comprises three, four or five major sides which are markedly non-parallel with each other, the total length of the

10 conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

The invention may still further be described as a RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-

15 circuited, the envelope of the spiral form comprising three major sides disposed so as to lie in a triangular relationship, the total length of the conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands. Preferably the one end is the outer end.

An end of each major side may merge with an end of an adjoining major side. The lengths

20 and angles between the major sides may be such that the antenna is linearly polarised.

It will be appreciated that the spiral need not be strictly planar; for example the antenna can be conformed to a slightly curved surface such as a vehicle window or body panel. Indeed, especially if the antenna is mounted in a concealed location, it could be markedly non-planar

25 eg. in the form of a helical spiral, provided that the functional requirements are achieved.

The aspect ratio of an overall envelope of the spiral form may be chosen such that the antenna has a required ratio of longitudinal and vertical polarisation. The overall envelope

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of the spiral form may be substantially in the shape of an equiangular triangle. Alternatively, it may be in the shape of an isosceles triangle, and preferably, in use, a top side of the overall envelope of the spiral is shorter than the other two sides of the overall envelope.

5   Co-extensive parts of the spiral form may extend parallel to each other. In a particular form of the antenna, when the antenna is disposed generally upright, from its one end the conductor may be adapted to extend upwardly at an angle, then generally horizontally, then generally downwardly at an angle to a point adjacent its one end, thereby forming a first outer side, a top outer side and a second outer side, respectively, and then to extend upwardly, horizontally and downwardly within the outer sides to form a first inner side, a

10   top inner side and a second inner side, respectively. Preferably, the first and top inner sides are each approximately 0.8 as long as the respective first and top outer sides, and the spacing between the first outer side and first inner side and between the top outer side and the top inner side are each approximately 0.1 of the length of the first outer side. The second inner side may be approximately one-third the length of the second outer side.

15   By "generally co-extensive sections" is meant sections of the spiral form, which whilst not necessarily of the same length, extend generally alongside and preferably parallel to each other.

One end of the conductor may be an outer end of the spiral form.

The antenna may also also comprise a stub antenna extending from the one end of the

20   conductor so as to be alongside an outermost portion of the spiral form, the stub antenna providing a required additional resonant frequency.

In the particular form of the antenna described above, the stub antenna preferably extends from the one end of the conductor so as to be alongside the first outer side and, more preferably, is approximately 0.4 the length of the first outer side. Even more preferably, the

25   spacing of the stub antenna from the first outer side is approximately 0.1 the length of the stub antenna. In this configuration, the antenna has resonant frequencies at approximately 100 MHz and 220 MHz.

The antenna may be mounted on a substrate for attachment to a window or other surface.

The antenna may comprise a ground plane functionally adjacent the conductor.

Alternatively the antenna may be in combination with a further said antenna, the two antennas being arranged as a dipole.

5   The invention also provides a window or vehicle body panel or other vehicle fitment comprising an antenna as set forth above.

The window or panel may form a dielectric between the antenna and the ground plane.

In another aspect the invention provides a method of manufacturing an antenna, comprising disposing or defining a single conductor in a polygonal spiral form with a feed connection

10   at or adjacent one end thereof, selecting the spacing between adjacent co-extensive sections of the polygonal spiral form and/or an overall length of the conductor such that the antenna has a plurality of required resonant frequencies. Preferably, the length and angles between successive sections of the polygonal spiral form are selected such that the antenna has a required ratio of horizontal and vertical polarisation.

15   Preferred features of the present invention will now be described, by way of example only, with reference to the accompany drawings, in which:

Figure 1 illustrates a first embodiment of the antenna of the invention;

Figure 2 illustrates a second embodiment of the antenna of the invention;

Figure 3 is a more detailed view of the antenna of Figure 1;

20   Figure 4 illustrates a third embodiment of the antenna of the invention;

Figure 5 shows the frequency response of the antenna of Figure 3;

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Figure 6 shows the frequency response of an antenna with conductor length of 110mm;

Figure 7 shows the polar radiation pattern of the antenna of Figure 3.

Figures 8 to 14 further illustrate the effects of varying the overall length of an equiangular triangular spiral antenna and varying the spacing of its turns.

5   Figures 15, 16 and 17 illustrate further possible shapes of an antenna according to the invention.

Figures 18 to 21 are drawings illustrating triangular antenna radiation polarisation.

Figure 1 shows the basic shape of one type of antenna according to the invention. It is in the form of a triangular spiral 10 in which the included angles between adjacent sides 12, 14

10   are equal (60°) ie. each turn of the spiral, and the overall envelope of the spiral, is substantially an equilangular triangle.

The spiral consists of a single length of wire having a terminal for connection at its outer end 18 to one conductor of a co-axial transmission line. The antenna is disposed adjacent a ground plane 20, which has a terminal 22 for connection to the other (shielding) conductor

15   of the co-axial line. Alternatively, a coplanar pair or other suitable transmission line may be used.

The spiral 10 may conveniently be printed on or embodied in the rear or other window of a motor vehicle, by known techniques, the ground plane 20 being provided by an adjacent metal panel of the car body in which the window is fitted.

20   Thus, in particular, the roof of the vehicle can be utilised as the ground plane. With the increasing use of plastics or other non-metallic materials for vehicle body panels and bumpers (fenders) and other vehicle body fitments, it alternatively may be convenient to embody the antenna on or in one of these parts. The antenna could be provided as a wire enclosed in a flexible film for this purpose.

The lowest (fundamental) resonant frequency is determined by the overall length and number of turns of the spiral. Because the position of the outer end is determined by the terminal 18, the innermost side of the spiral 24 may be foreshortened, eg. in Figure 3. A further resonant frequency is attained from the spacing of the co-extensive corresponding parts of

5   the spiral.

A stub antenna 26 is provided alongside and parallel to the outermost side 28 to provide another resonant frequency, as discussed below. Further stub antennas may be provided, preferably extending generally parallel to antenna 26 to provide yet further resonant frequencies in other bands. The resonant frequency of the stub antenna is determined

10   primarily by its length, but may also be affected by reactive coupling to an adjacent portion of the antenna.

An alternative form of antenna is shown in Figure 2. Here, two triangular spirals 10 as already described are arranged relative to each other so as to form a dipole, the ground plane being dispensed with. The terminals 18, 20 preferably are connected to a balanced

15   transmission line or to a twisted pair with balun, as known per se.

Referring to Figure 3, the dimensions of the spiral 10 of Figure 1 are given, as determined in a prototype which gives mixed polarisation coverage for the following bands:

         AM (140-283KHz & 526-1607KHz)
         FM European (88-108MHz) or Japan 76-90MHz)
20   DAB1 (217.5-230MHz)
         DAB2 (1452-1492MHz)

Other frequency bands can be covered by choosing suitable dimensions for the structure, as discussed below. The antenna can incorporate an amplifier to give increased sensitivity at each band.

25   The side projection stub 26 provides matching at the higher frequency band (DAB2) and the remaining spiral geometry sets the lower frequency bands. The resonant frequencies of the triangular spiral can be changed by varying the values of h (the height of the antenna) and d (the conductor spacing). By varying the value of d the inductance between adjacent parts

of the antenna changes and hence the loading of the structure changes, thereby changing the effective electrical length of antenna. The overall length of the line constituting the spiral antenna also can be increased or decreased thus changing the operating band frequencies and the number of operating bands. The geometry may also change so that the number of turns

5   on the spiral increases or decreases, depending on the overall length.

The spiral shown in Figure 3 has equal angles. If the angles are changed, hence changing the aspect ratio, for example as shown in Figure 4 so that the shape becomes akin to an isosceles rather than an equilangular triangle, then the ratio of vertical polarisation to horizontal polarisation power radiated will change. This is useful where mixed polarisation

10   broadcasting is used such as FM radio and TV in the UK and provides easy adjustment with this type of antenna.

The synthesis of an antenna design from first principles is mathematically complicated, and design can with advantage be approached empirically. The main principles are as follows:

The overall length of conductor in the spiral determines the lowest operating frequency,

15   hence a long antenna will operate at a lower frequency while a short antenna will operate at a higher frequency.

The stub 26 determines the frequency of the highest band - it resonates as a $\lambda/2$ monopole, modified by its proximity to the main conductor.

The gap between the adjacent turns or parts thereof affects several parameters. In effect the

20   gap determines the mutual coupling between the conductors:
-       a narrow gap leads to a shorter antenna;
-       the gap width tunes the intermediate frequency band;
-       the width of the gap determines the frequency bandwidth at the lower bands - increasing the gap increases the bandwidth;

25   -   differential gaps can be set between the sides - in other words the gaps are not all equal between each arm - this allows adjustment of the bandwidths of different frequency bands;

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-       horizontal to vertical polarisation ratio is determined by the lengths and selective
        angles of the major sides as discussed hereafter with regard to Figure 18.

Figure 5 plots the resonances of the antenna of figure 3. There are resonant frequency bands
near 100MHz, 220MHz and 1470MHz. The AM band does not utilise a resonant structure.

5   Figure 6 shows the effect of increasing the overall length from 65mm as in Figure 3 to
110mm. The number of resonances increases with new resonances at 370 and 480MHz, and
the lowest frequency of resonance reduces to 40MHz.

Sensitivity (gain) tests show that the performance of the antenna is comparable with mast
antennas. The bandwidth at all bands can be improved with an active matching circuit which

10   can also provide gain and hence the possibility of improved sensitivity.

The radiation patterns in Figure 7 show the comparison between the triangular spiral antenna
of Figure 3 mounted on the rear passenger side window of a car and a reference monopole
mounted on the roof of the same car. The gain of the active spiral is higher than that of the
monopole except for a null near 40° due to blocking by the c-pillar on the car. The pattern

15   off-car is symmetrical and very similar to a monopole.

Figures 8 to 12 further illustrate the effects of varying the overall length of an equiangular
triangular spiral antenna and the spacing of its turns. Each plot is of return loss (dB) against
frequency (MHz) of an antenna configured as in Figure 8c. The return loss equates to the
matching of the antenna VSWR, the deeper and wider the nulls (more negative on the plot),

20   the better the matching and the bandwidth.

Figure 8a shows the return loss of an antenna having an overall length of 135mm, and a
separation d of 10mm. Figure 8b shows the return loss for the same antenna with d
increased to 15mm. This results in a deeper null at 95MHz, (ie. better matching of the
resonance to the European FM broadcast band) and a slightly improved bandwidth. However

25   the resonance 275MHz is much more dependent on the spacing d and is moved to about
220MHz, and is made much wider, resulting in better matching of the antenna to the DAB
1 band over a wider bandwidth.

The resonance for the European FM band can be maintained for varying antenna lengths by varying the spacing d. Increasing d with length can maintain this resonance at an approximately constant frequency, but the higher resonance at 200 + MHz moves, so this resonance effectively can be tuned. Thus, Figure 9 (length = 63mm, d = 3mm), Figure 10

5   (length = 100mm, d = 5mm), Figure 11 (length = 177mm d = 20mm) and Figure 12 (length = 195mm d = 25mm) and also Figure 8b (length = 135mm d = 15mm) show that an antenna for the European FM band (88-108 MHz) and the DAB 1 band (217.5-230 MHz) can be achieved with various combinations of antenna length and spacing. Thus there is considerable flexibility to tailor the antenna to the space available.

10 The FM band is approximately 3 metres wavelength. An antenna that has an approximate diameter of one-half wavelength will exhibit circular polarisation. The dimensions of the antenna shown in Figure 3 has a cross-dimension (one corner to the middle of an opposite side) that is much less than one-half wavelength, and thus this antenna has negligible circular polarisation.

15 Figures 13 and 14 illustrate still further the effects of varying the spacing between the turns of a triangular spiral antenna. Figure 13 illustrates the configuration of the antenna. It has a first outer side 100, a top outer side 101, a second outer side 102, first inner side 103, and top inner side 104. The first outer side 100 and first inner side 103 are parallel and spaced from each other by the gap "b". The top outer side 101 and top inner side 104 are parallel

20 and spaced from each other by the gap "a". With the overall length of the antenna fixed and the gap "a" fixed at 10mm, gap "b" was varied between 5mm and 30mm to examine the effect on resonant frequency and bandwidth. The resultant tuning and bandwidth are shown in Figure 14.

From Figure 14 it can be seen that the frequency bands of interest are centred on 100MHz

25 and 220MHz. At 100MHz, increasing gap "b" increases the resonant frequency. Increasing gap "b" significantly widens the band (bandwidth). At 220MHz, the resonant frequency is approximately constant. The width of the band (at -5dB on Figure 14) is affected only slightly by the size of gap "b".

Several variations based on the foregoing principles are evident. For example, the spiral may be in the form of a regular or irregular triangle (adjacent parts of each turn of the conductor remaining parallel) in which opposite sides are markedly non-parallel, or the spiral may be arranged in some other regular or irregular polygonal shape. An irregular quadrilateral

5   spiral, for example, can behave similarly to a triangular one, especially if one side of the quadrilateral is much shorter than the others so that its overall envelope tapers sharply to one end, as shown in Figure 15. Regular polygons with six or more sides are unlikely to be effective, since they are approaching a circular outline, but a regular (Figure 16) or irregular polygon may have utility. For example, an irregular hexagon in which very short sides

10   alternate with long ones results in a generally triangular envelope with the corners of the triangle 'chamfered-off', as shown in Figure 17. Such a configuration is effectively triangular and can be expected to behave as such. Effectively the three major sides 30, 32, 34 lie in a triangular relationship and are joined together and to the remainder of the spiral by intervening short sides 36, 38, 40. In contrast, in the triangular spiral of Figure 1 or the

15   quadrilateral or pentagonal spirals of Figures 15 and 16 , each major side defining the envelope (42, 44, 46, 48 in Figure 15) has an end which merges with an end of an adjoining major side. The principle remains to determine resonant frequencies by adjusting the overall length, and/or the spacing of the adjacent parts of the conductor, and/or by adjusting the aspect ratio. Adjacent lengths of conductor should normally be generally parallel, although

20   non-parallel configurations may be found advantageous in some cases eg. for control of bandwidth.

Still in accordance with the foregoing principles, the antenna feed may be at the inner end of the spiral rather than the end. In that case the stub antenna 26 also is arranged at the inner end of the spiral.

25   Figure 18 illustrates how relative horizontally and vertically polarised radiation can be adjusted. The figure shows an antenna having a triangular outer envelope and comprised of five connected linear sections '1' to '5' as shown. The radiation from the conductor is linear and the current decays as it travels along the arms so that it is strongest in arm 1 and weakest in arm 5. If the decay is linear, then on average arm 1 has 5 times the current of arm 5.

10

Figure 19 illustrates the currents in the five arms of the Figure 18 antenna resolved into horizontal and vertical vectors. The number under each of the vectors corresponds to the arm with the same number in Figure 18. Figure 20 illustrates the currents present if arm 5 is removed, and Figure 21 illustrates the currents present if both arms 4 and 5 are removed.

5   Thus the relative strengths of the polarised radiation can be changed. In this simple illustration the resonant frequencies also will change with the change in length and configuration of the antenna, but the principle of adjusting the radiation vectors can be applied together with the other design principles set out earlier, especially by changing the lengths and relative angles of the sections of the polygonal antenna.

10   Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

Statements in this specification of the objects or advantages of the invention relate to preferred embodiments of the invention, but not necessarily to all embodiments of the
15   invention falling within the claims.

The text of the abstract filed herewith is repeated here as part of the specification.

A RF antenna comprises a single conductor arranged in a generally spiral triangular form, and means for connecting the conductor to an antenna feed at or adjacent one end of the spiral, the other end of the spiral being open-circuited.

CLAIMS:

1.   A RF antenna comprising a single conductor arranged in polygonal spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, the polygonal spiral form comprising successive linear sections each forming an angle with a succeeding or preceding one, the total length of the conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

2.   An antenna as claimed in claim 1, wherein the lengths of the sections and the angles between them are such that the antenna is linearly polarised.

3.   An antenna as in claim 1 or 2, wherein opposite sides of the generally spiral form comprises at least three major sides which are markedly non-parallel with each other.

4.   A RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, wherein the envelope of the generally spiral form comprises three, four or five major sides which are markedly non-parallel with each other, the total length of the conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

5.   A RF antenna comprising a single conductor arranged in a generally spiral form, and means for connecting the conductor to an antenna feed at or adjacent one end of the conductor, the other end of the conductor being open-circuited, the envelope of the spiral form comprising three major sides disposed so as to lie in a triangular relationship, the total length of the conductor and the spacing of adjacent co-extending sections being such that the antenna exhibits resonances in a plurality of frequency bands.

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6.   An antenna as in any of claims 3, 4 or 5, wherein an end of each major side merges with an end of an adjoining major side.

7.   An antenna as claimed in any of claims 3, 4 or 5, wherein the lengths and angles between the major sides are such that the antenna is linearly polarised.

8.   An antenna as claimed in claim 7, wherein the aspect ratio of the overall envelope of the spiral form is chosen such that the antenna has a required ratio of horizontal and vertical polarization.

9.   An antenna as claimed in any of claims 4 to 8, wherein an overall envelope of the spiral form is substantially in the shape of an equiangular triangle.

10.   An antenna as claimed in any of claims 4 to 8, wherein an overall envelope of the spiral form is substantially in the shape of an isosceles triangle.

11.   An antenna as claimed in claim 10, wherein, when the antenna is disposed generally upright, a top side of the overall envelope of the spiral form is shorter than the other two sides of the overall envelope.

12.   An antenna as claimed in any preceding claim, wherein co-extensive parts of the spiral form extend generally parallel to each other.

13.   An antenna as claimed in claim 9, wherein, when the antenna is disposed generally upright, from its one end the conductor is adapted to extend upwardly at an angle, then generally horizontally, then generally downwardly at an angle to a point adjacent its one end, thereby forming a first outer side, a top outer side and a second outer side, respectively, and then to extend upwardly, horizontally and downwardly within the outer sides to form a first inner side, a top inner side and a second inner side, respectively.

14.   An antenna as claimed in claim 13, wherein the first and top inner sides are each approximately 0.8 as long as the respective first and top outer sides, and wherein the spacing between the first outer side and first inner side and between the top outer side and the top inner side are each approximately 0.1 of the length of the first outer side.

15.   An antenna as claimed in claim 14, wherein the second inner side is approximately one-third the length of the second outer side.

16.   An antenna as claimed in any preceding claim, wherein the one end of the conductor is an outer end of the spiral form.

17.   An antenna as claimed in any preceding claim, and also comprising a stub antenna extending from the one end of the conductor so as to be alongside an outermost portion of the spiral form, the stub antenna providing a required additional resonant frequency.

18.   An antenna as claimed in claim 13, 14 or 15, and also comprising a stub antenna extending from the one end of the conductor so as to be alongside the first outer side.

19.   An antenna as claimed in claim 18, wherein the stub antenna is approximately 0.4 the length of the first outer side.

20.   An antenna as claimed in claim 19, wherein the spacing of the stub antenna from the first outer side is approximately 0.1 the length of the stub antenna.

21.   An antenna as claimed in claim 20, wherein the antenna has resonant frequencies at approximately 100 MHz and 220 MHz.

22.   An antenna as claimed in any preceding claim, further comprising a ground plane functionally adjacent the conductor.

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23. An antenna as claimed in any preceding claim, in combination with a further said antenna, the two antennas being arranged as a dipole.

24. An antenna as claimed in any preceding claim, mounted on a substrate for attachment to a window or other surface.

25. A window or vehicle body panel or other vehicle fitment comprising an antenna as claimed in any preceding claim.

26. A window or vehicle body panel or other vehicle fitment as claimed in claim 25, wherein the window or body panel forms a dielectric between the antenna and the ground plane.

27. A method of manufacturing an antenna, comprising disposing or defining a single conductor in a polygonal spiral form with a feed connection at or adjacent one end thereof, and selecting the spacing between adjacent co-extensive sections of the polygonal spiral form and/or an overall length of the conductor such that the antenna has a plurality of required resonant frequencies.

28. A method as claimed in claim 27 comprising selecting the length and angles between successive sections of the polygonal spiral form such that the antenna has a required ratio of horizontal and vertical polarisation.

15

Fig. 1

Fig. 2

150 mm

d=17.3 mm

49.2 mm

117.3 mm

h=139.9 mm

150.3 mm

122.7 mm

60.3 mm

L

10 mm

7 mm

Fig. 3

Fig. 4

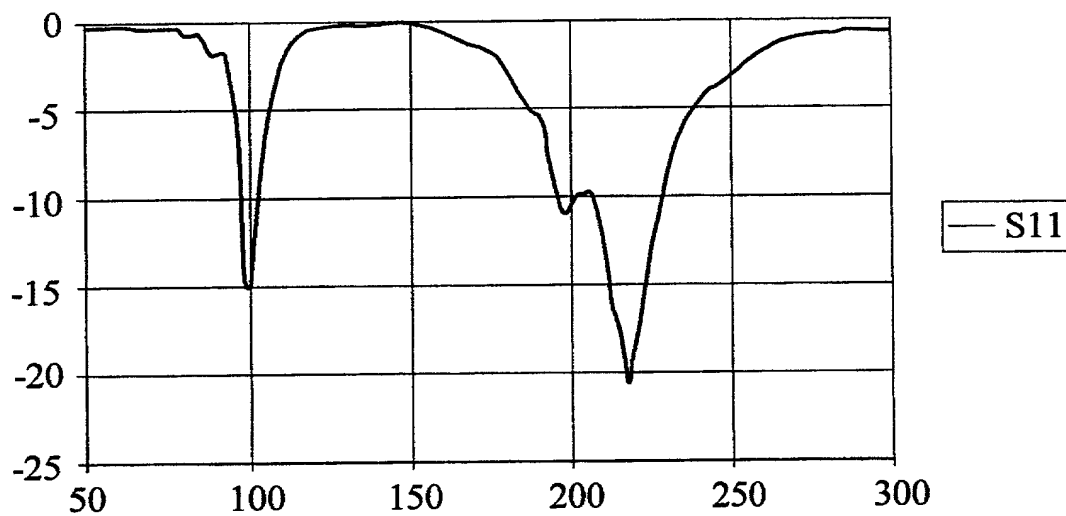Comparison between Measured and Simulated S11
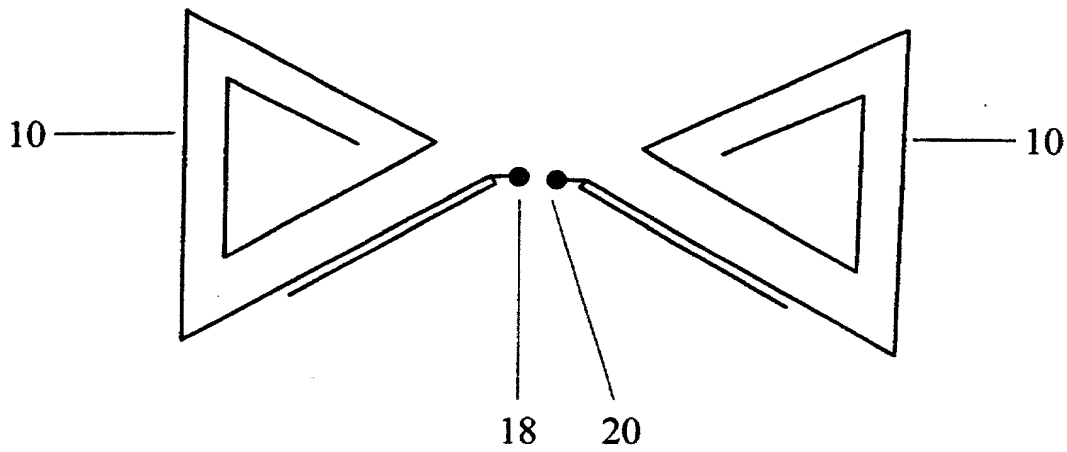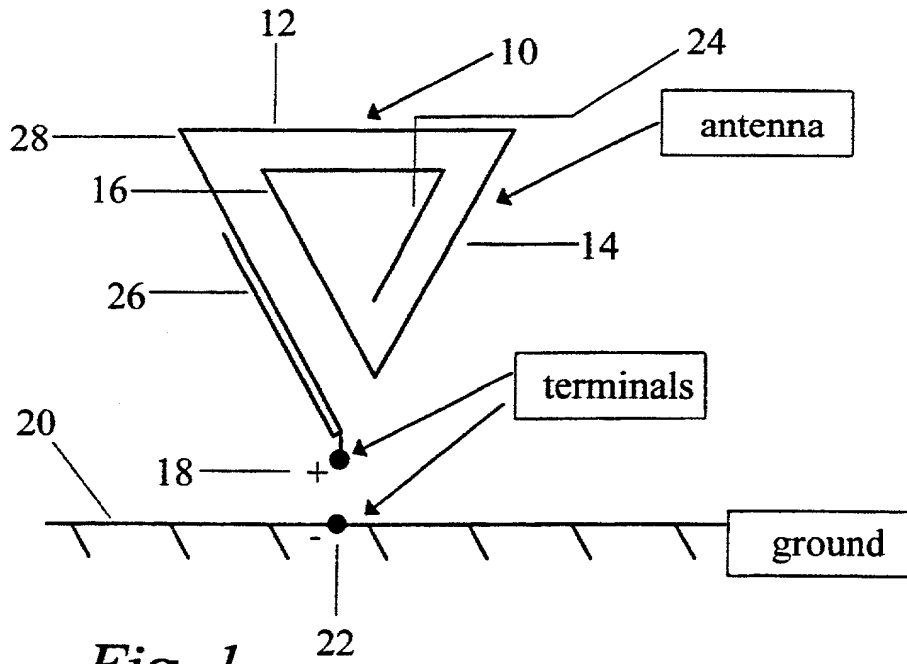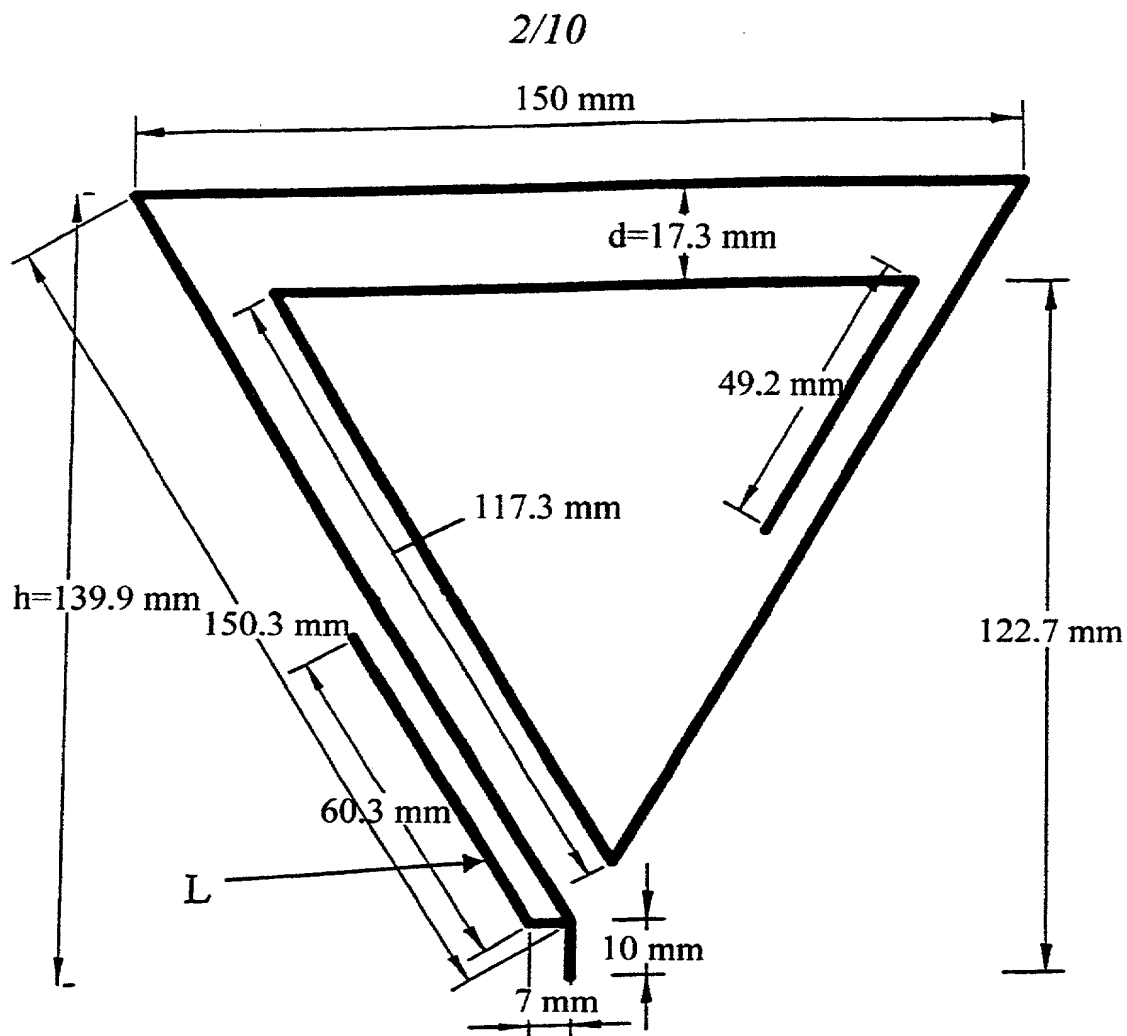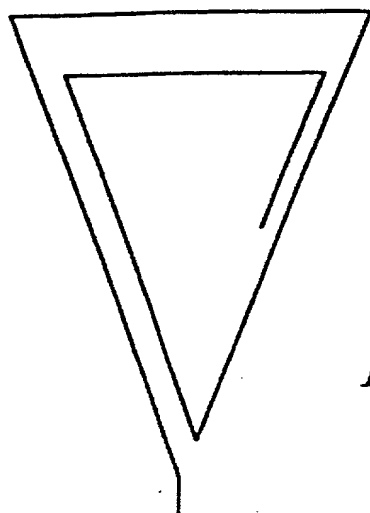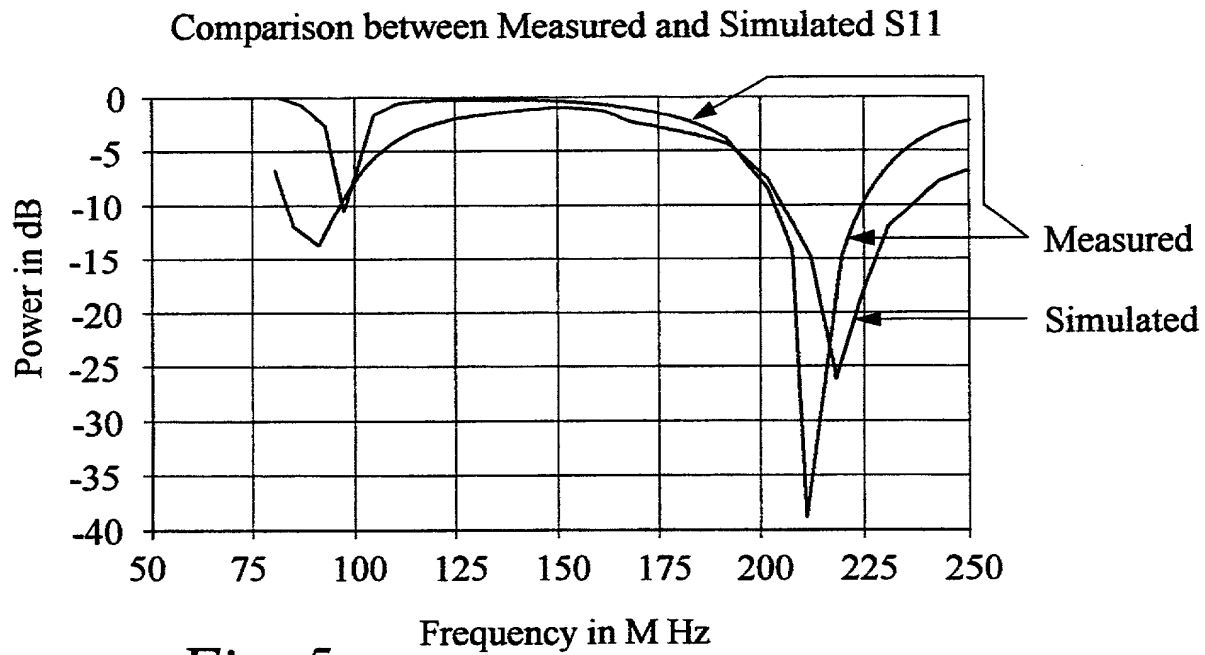
Fig. 5

Fig. 8C
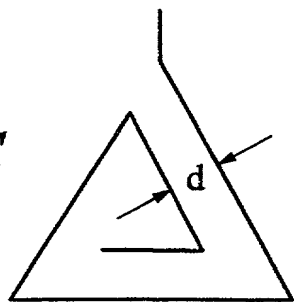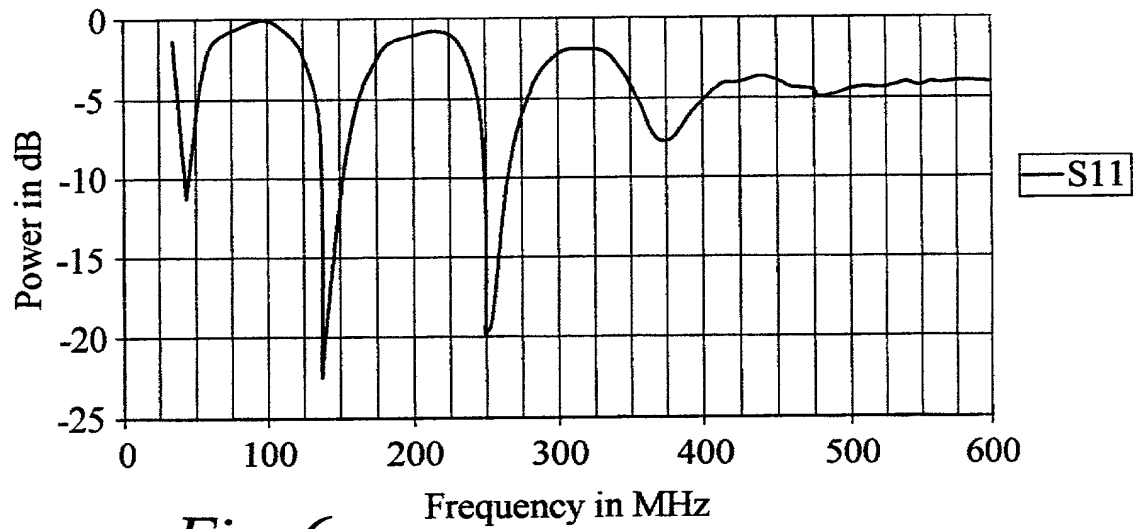
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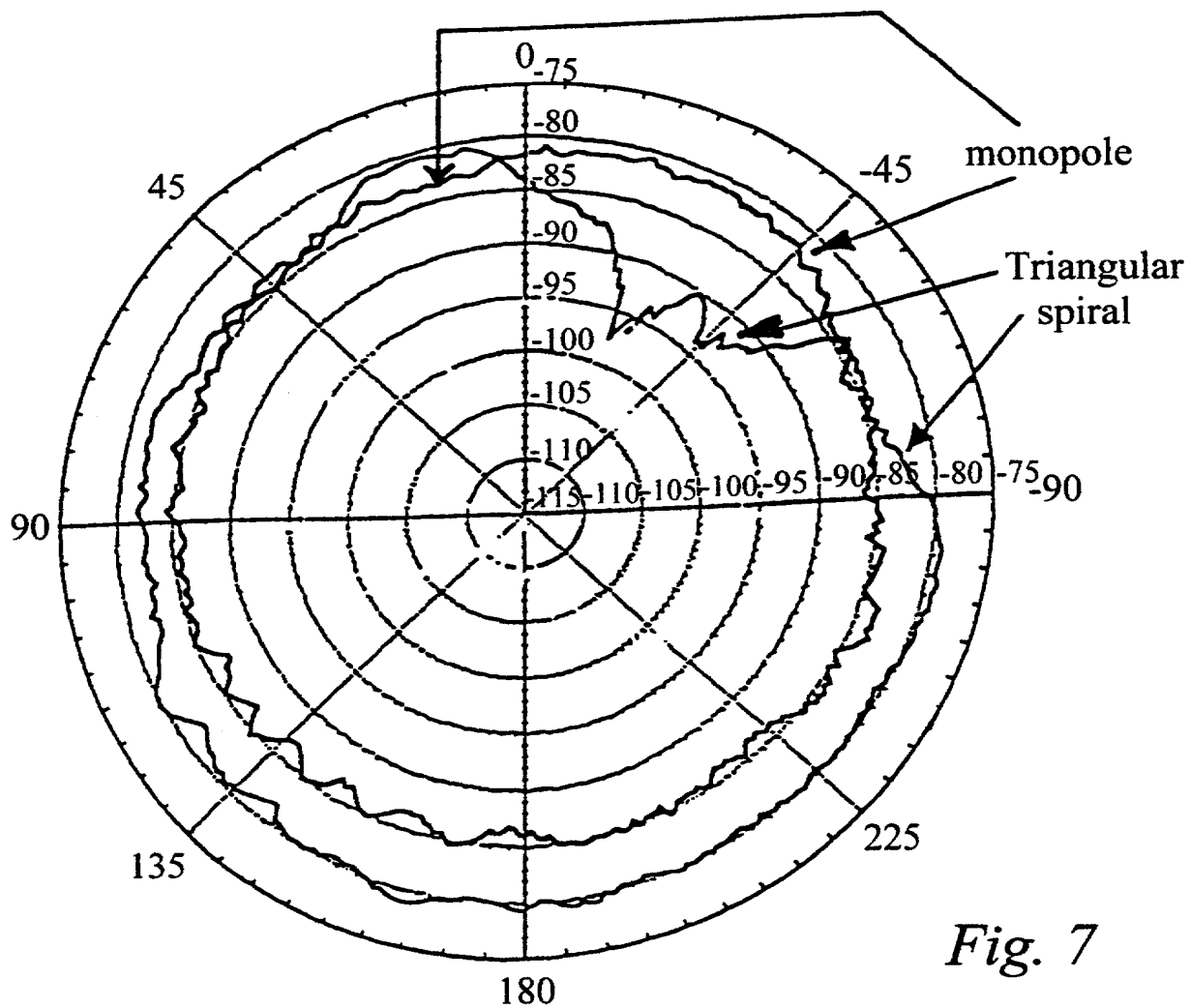
Fig. 7

Triangular Spiral with d=10mm and final length = 135mm
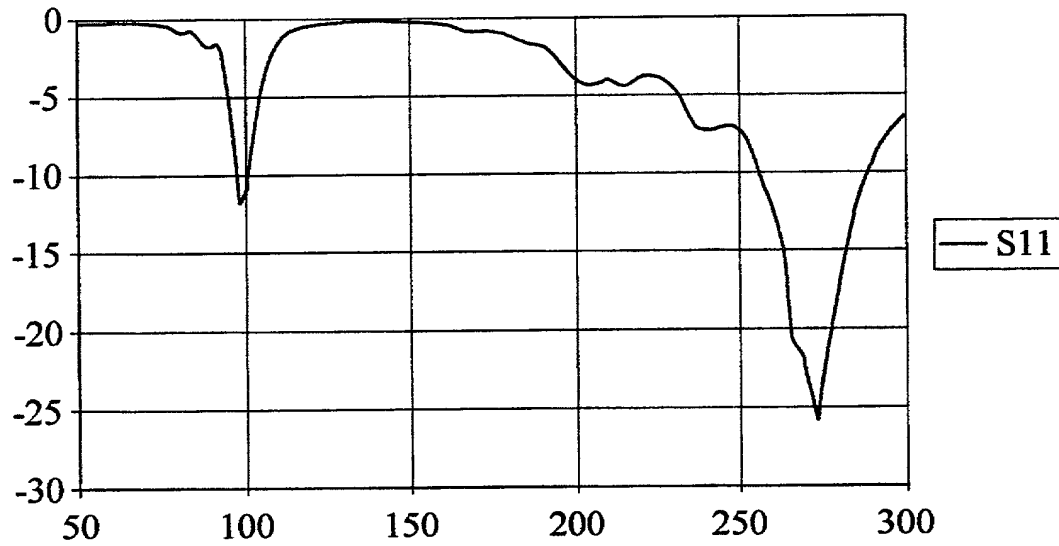
Fig. 8A

Triangular Spiral with d=15mm and final length = 135mm
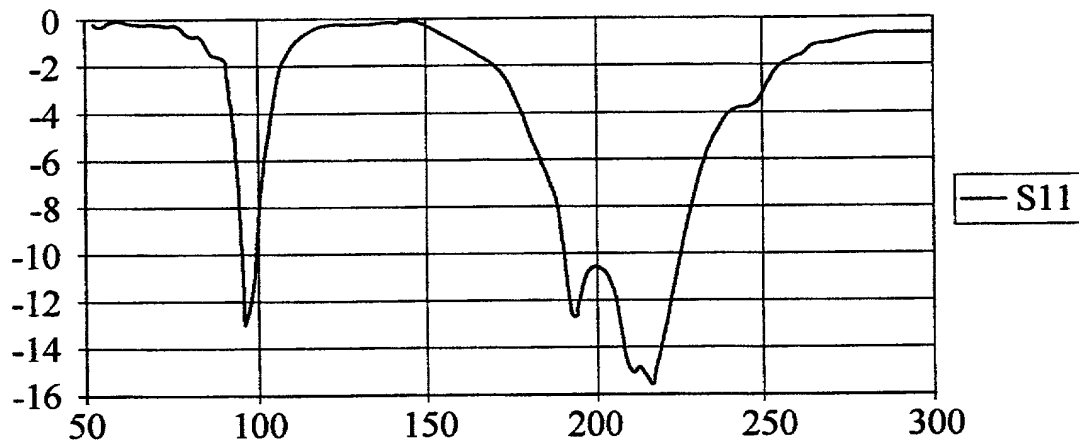
Fig. 8B

Triangular Spiral with d=3mm and final length = 63mm
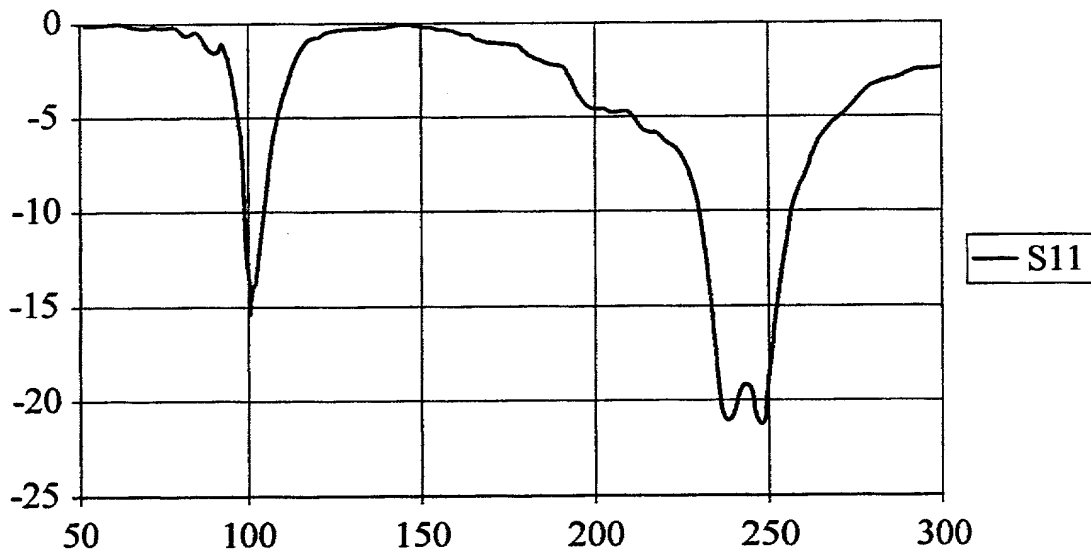
Fig. 9

Triangular Spiral with d=5mm and final length = 100mm
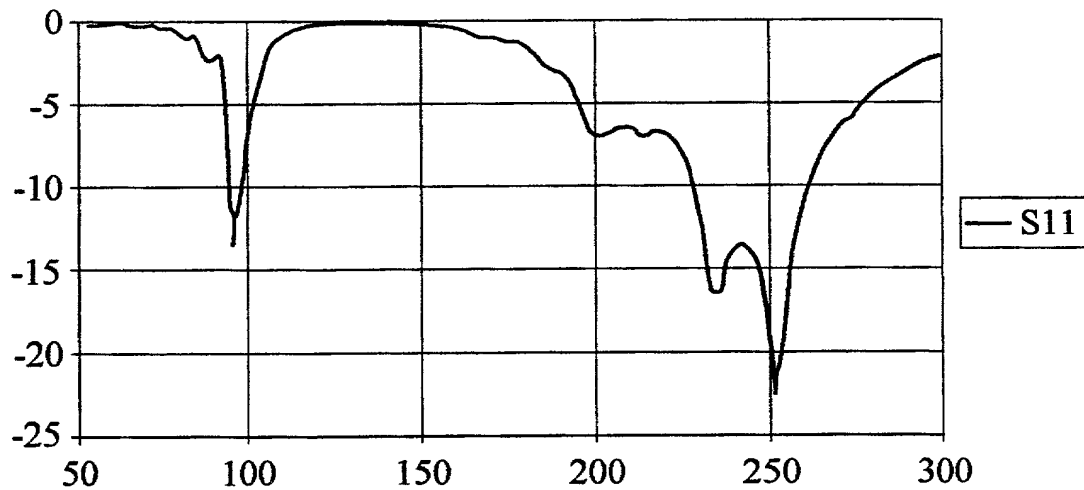
Fig. 10

Triangular Spiral with d=20mm and final length = 177mm

Fig. 11

Triangular Spiral with d=25mm and final length = 195mm
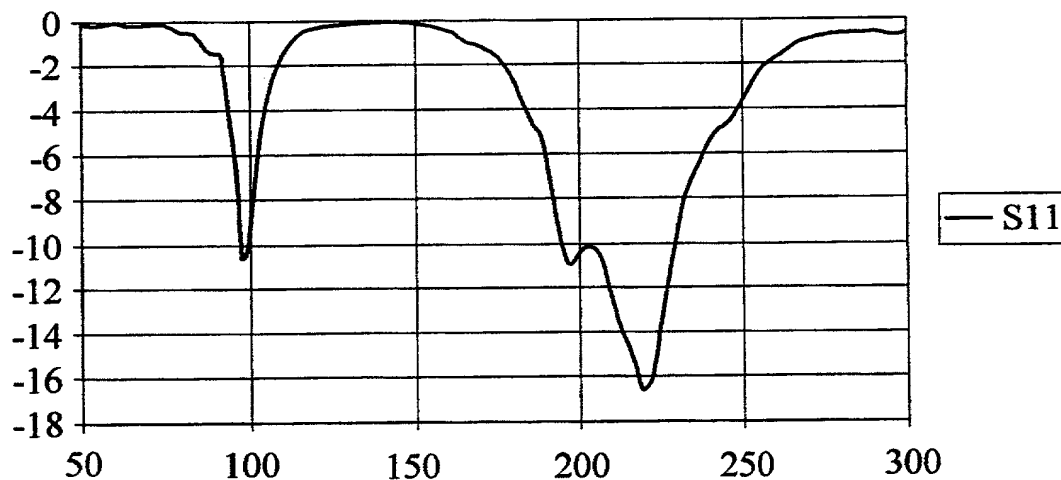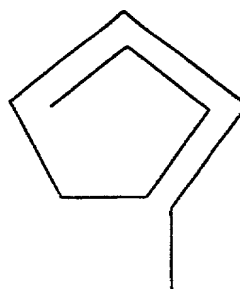

Fig. 12
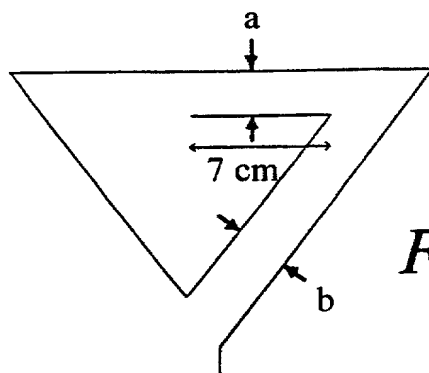
Fig. 13

Fig. 15

Fig. 17

Fig. 16

Fig. 14

Fig. 18

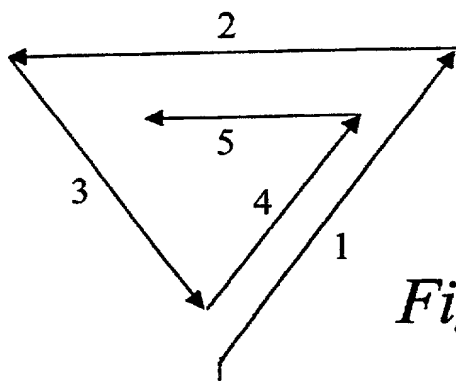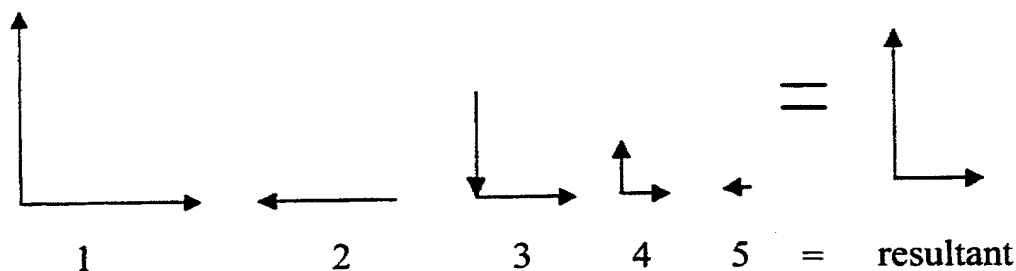1   2   3   4   5   =   resultant
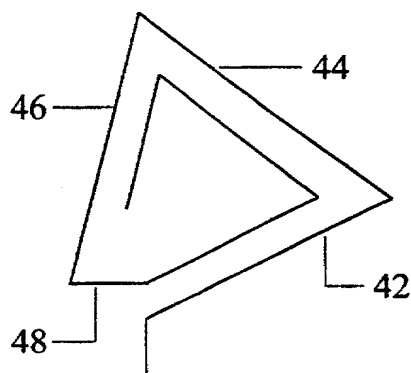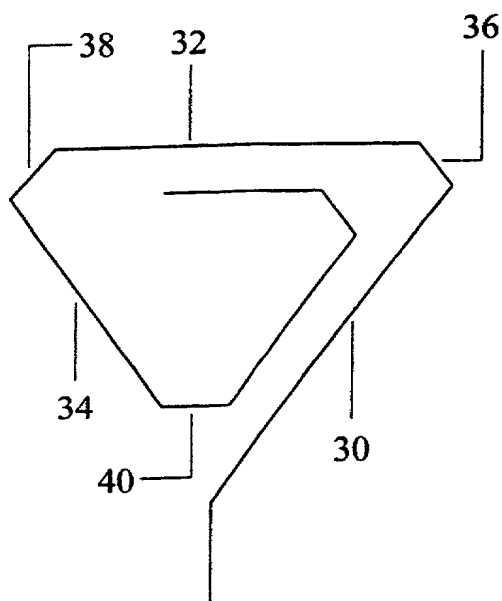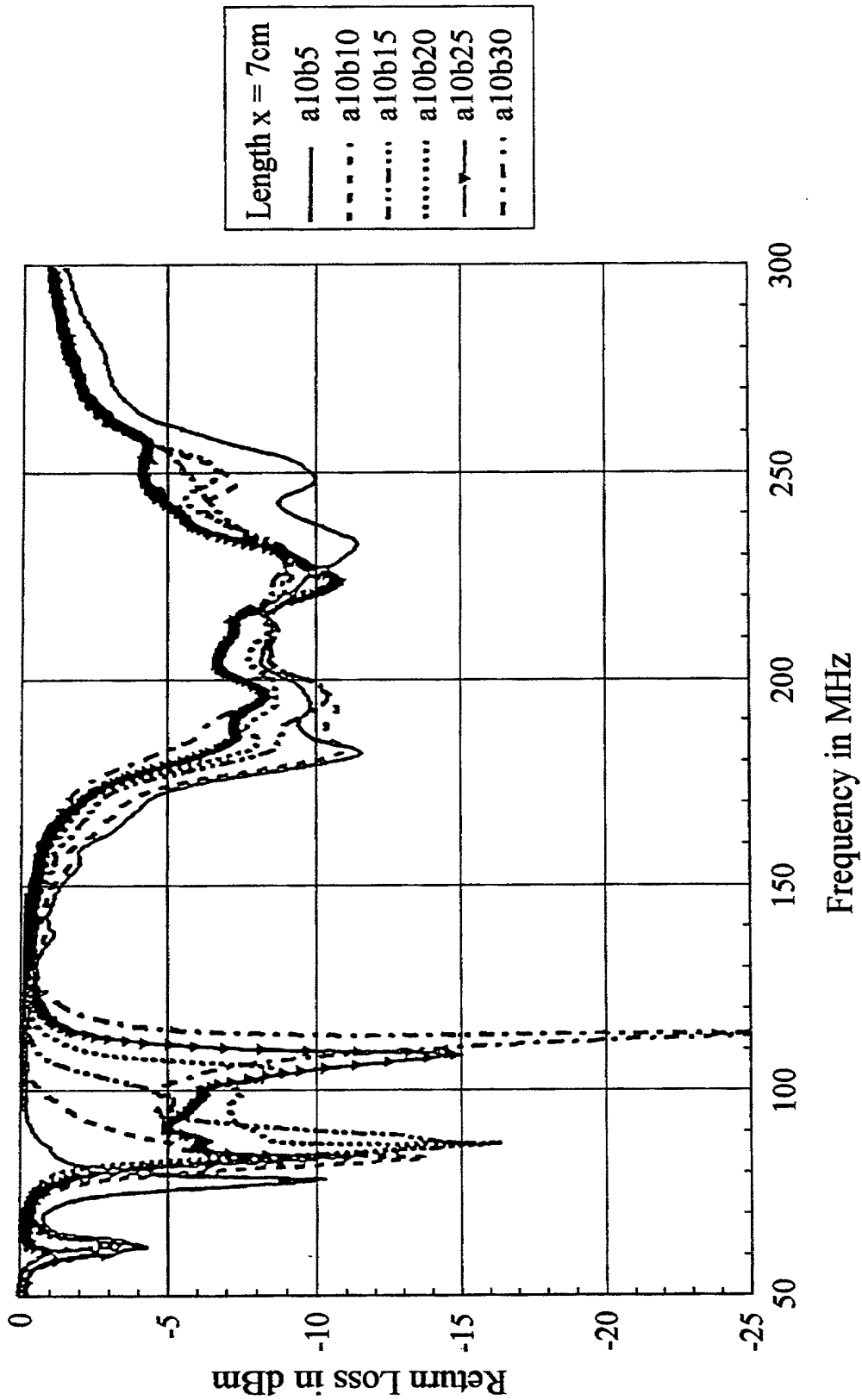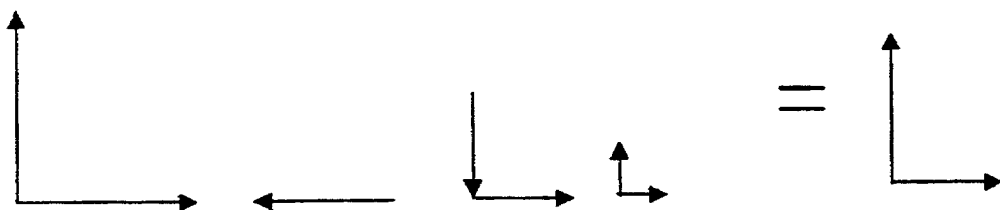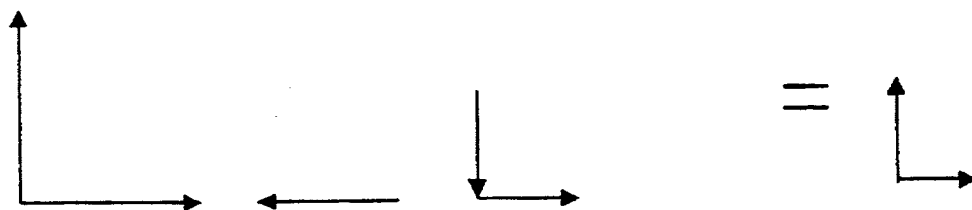
Fig. 19

Fig. 20

Fig. 21

DECLARATION AND POWER OF ATTORNEY
(UNASSIGNED NONPROVISIONAL APPLICATION)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below at 201 et seq. underneath my name.

I believe I am the original, first and sole inventor if only one name is listed at 201 below, or an original, first and joint inventor if plural names are listed at 201 et seq. below, of the subject matter which is claimed and for which a patent is sought on the invention entitled

Multiband Antenna

and for which a patent application:
□ is attached hereto and includes amendment(s) filed on
□ was filed in the United States on   as Application No.
with amendment(s) filed on
☑ was filed as PCT international Application No. PCT/GB00/02274   12/06/00   and was amended under PCT Article 19 on

I hereby state that I have reviewed and understand the contents of the above identified application, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

EARLIEST FOREIGN APPLICATION(S), IF ANY, FILED PRIOR TO THE FILING DATE OF THE APPLICATION			
APPLICATION NUMBER	COUNTRY	DATE OF FILING (day, month, year)	PRIORITY CLAIMED
No. 9913526.1	United Kingdom	10 June 99	YES ☑ NO □
			YES □ NO □

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below.

APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

APPLICATION SERIAL NO.	FILING DATE	STATUS		
		PATENTED	PENDING	ABANDONED

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NY2 - 1277228.1

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	POST OFFICE ADDRESS	STREET	CITY	STATE OR COUNTRY	ZIP CODE
		SIGNATURE OF INVENTOR 205		DATE

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